Researching of the factors determinant safety movement of the train in braking regime – impact of braking force on the superstructure of the railway with regard to the interoperability and the experience of the railway section Gorna Oryahovitsa

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Abstract: The horizontal reaction of the rail is very important to the creation of the braking force. The value of rail reaction is equal to the value of the braking force. The subject of the article is the determination of braking force in two different ways. The first is based on braking pressure for one braking jay and friction between braking jay and wheel for vehicles equipped with block brake. The second is based on braked weight and braked weight percentage. The theoretical results obtained by the two methods are compared on the basis of the need for interoperability under Regulation 1299/2014 relating to Infrastructure subsystem of the rail system of the EU. The practical impact of braking force in declivities with a gradient of slope over 15 % has been established on the basis of direct observations and analyzes. The experience in the operation of heavily inclined sections of the Gorna Oryahovitsa railway section has been used.

Keywords: BRAKING FORCE, BRAKING WEIGHT, TRAIN, RAILWAY TRACK, SLOPE-DOWN MOVEMENT

1. Introduction

The slope-down movement of the train requires the using of braking force to maintain a safety running speed. Applied to the wheel-rail contact plane, this braking force causes a horizontal reaction in the rail and additionally loads the elements of the railway superstructure. For the design of railway lines, this braking force can be determined using approximate methods. The calculation of the braking force is done in an easy-to-apply manner based on the friction between the cast-iron brake shoes and the wheel. This method is different from the requirements for calculation of the braking force based on braked weight and braked weight percentage given in UIC methodology. The comparison of calculation methods of braking force would be useful in terms of updating and technical harmonization of the principles of designing railway lines. The other side of the examination is the effect that the braking force has on the elements of the upper structure. The other side of the examination is the effect of the braking force on the elements of the superstructure. The impact can be assessed on the base of direct observations, data collection, and analysis of road conditions in heavily inclined sections.

2. Comparison of the methods for determining braking force. Determine the additional load on the superstructure of the track that it causes

2.1. Determination of braking force based on the friction between the cast iron brake shoes and the wheel

The pressure of the brake shoes on the wheels of one brake axle causes friction force [1, 2]. The internal force pair BBᵢ appears (fig.1). The force transmitted on the rail is Bᵢ; Bᵢ is limited by the force of adhesion.

\[ Bᵢ = Kφk (1,2) \]

Where K [kN/axle] – pressure for one brake axle; φk – factor of friction brake shoes and wheel.

![Fig.1 Creating the braking force](image)

The Bᵢ force causes the reactive external force Bᵢ and they balance each other. Only force B remains to act, but it is conditioned by the appearance of B₀. The force B₀ is limited by the adhesion force by K and φₜ.

\[ B₀ = 10Kφₜ ≤ 10φQ₁ \]

Where: B₀ [kN] – rail reaction; Q₁ [t] – weight for one axle; ψ – factor of cohesion between wheel and rail.

The factor φₜ depends on the speed, the pressure of one brake shoe and the material of the friction surfaces. The factor φk is the connection between speed and brake force.

\[ φk = 0.6 \frac{1.6k + 100V + 100}{8k + 100V + 5V + 100} \]

Where: k [kN] – brake pressure of one brake block; V [km/h] – speed.

The full braking force Bᵢ [kN] for the train as a whole is:

\[ Bᵢ = \sum B₀ = l0Kφk \]

Where: Bᵢ [kN] – full braking force; B₀ [kN] – sum of rail reaction for all braking axles; ΣK [kN] – total pressure force for the whole train; φₜ – factor of friction brake shoes and wheel.

Equation (4) can be used to calculate the full braking force of a train with the same braking equipment for all wagons. Calculating the braking force is more complicated for a train composed of wagons with different braking equipment. Average values of friction factor and pressure of one brake axle are used for easier calculation.

The described method makes it possible to calculate the additional load on the superstructure of the track caused by the reaction of the rail ΣB₀ at the moment of acting of braking force.

2.2. Determination of the braking force by the brake weight and the brake weight percentage

2.2.1. Braking performance according to UIC 544-1

Assessing the braking performance according to [3] are the brake weight B and the braked weight percentage λ. Braked weight percentage depends on stopping distance and speed and assessment diagrams are given. The reference train was equipped with block brakes with low-phosphorus cast-iron blocks.

The braking weight of wagon fitted with cast iron brake blocks maximum speed ≤120km/h, and maximum axle load 22.5t can be determined [3] by using equation (5):

\[ B = \frac{k\sum F_{dyn}}{g} \]
Where: $K_i$ braking weight; $k$ – assessment factor for determining the braked weight; $\Sigma F_{dyn}$ [kN] – sum of all brake block forces during the run; $g=9.81m/s^2$ – gravity acceleration.

The values of one brake block forces during the run for 2-axil and 4-axil wagons is given in [3].

2.2.2. Determination of braking force

Equation (4) can be used to calculate the brake force if total pressure force for the whole train $\Sigma K$ is known. The brake weight of wagon can be used to calculate the total pressure force of brake axles. The total brake pressure of wagon is:

$$6 \sum K_i = \frac{B}{x}$$

Where: $\Sigma K_i$ – total pressure force of one wagon; $B$ – brake weight; $x$ – empirical coefficient.

Substituting braking weight $B$ from equation (5) for total pressure force is obtained:

$$7 \sum K_i = \frac{k \sum F_{dyn}}{x}$$

Where: $\Sigma K_i$ [kN] – total pressure force of one wagon.

The total braking pressure for the train as a whole is:

$$8 \sum K = \sum \sum K_i = \sum \frac{k \sum F_{dyn}}{x}$$

Where: $\Sigma K$ [kN] – total pressure force of the train.

The full braking force is:

$$9 B_k = \sum \sum B_0 = \varphi_k \frac{k \sum F_{dyn}}{x}$$

In regulation 58 [5] are given the braking percentages according to the slope. Regulation 58 is harmonized [6] with UIC code 544-1.

3. Analysis of train running and permissible (allowable) speed as a function of railway track inclination

The diagram of resultant relative force in a braking regime (fig. 2) for a given railway line gives the limited slope value for maximum speed for every train. For slopes greater than the limited slope, it is necessary to reduce speed because of brake not because of the track geometry.

For example, Vakarel - Verinsko section with slope value 25‰, maximum speed 100km/h [9] has limited speed by braking 45km/h. The limit of speed increase traveling time. It is concluded that in order to increase speed, it is necessary to limit the slope values. According to [10] the slope of the moving average profile over 10 km is less than or equal to 25mm/m (25‰).

4. Impact of braking force on the superstructure of the railway with regard to the experience of the railway section Gorna Oriahovitsa

Sections in big acclivity are used to overcome difficult terrain conditions. These sections are often combined with horizontal curves with small radii in a situation. For example: the sections of the 4 railway line Borovo - Morunitsa from km 62+417 to km 65+585 with slopes between 21 and 27 ‰ and radii of curves between 250 and 355m and the section Plachkovtsi - Krastets from km 185+400 to km 192+945 s slopes between 17 and 26 ‰ and radii of curves between 275 and 300m. There is more intensive wear of the rails at the horizontal curves with small radii. Lubricants are used to reduce wear and tear, but the cohesion between the wheel and the rail is reduced too and braking is difficult. Very precise dosing of the lubricant is required, and nevertheless, there are registered problems.

Another problem is the danger of igniting from transfer flying sparks. Such cases are registered in the section Morunica - Byala, where the rails lie on timber sleepers. Ignition is caused by sparks from the braking block of freight trains.

The jumps are shifted in the direction of the slope and often the connection between the rails displaces beyond the zone of the sleeper. This is very difficult to repair within the current track maintenance. The problems with rotated sleepers and slipping of joints are increasing in sections in big declivities with heavy freight traffic. There are problems not only when the train moves down to the slope but and when a train moves in the opposite direction (acclivity). There is very big wear of the rails in these profile sections (fig. 3).
Fig. 3 Wear of the rails in section with big longitudinal slope

5. Conclusion

The method of calculating the braking force taught so far at UACEG can be successfully updated by using the braking weight and braking weight percentage given in recommendations of UIC code 544-1. The following can be said about analyze train movement in braking regime:

1. Braking regime is used not only when braking is necessary, but also to maintain a safe speed of moving.
2. By increasing the slope, the permissible speed because of a brake is reduced.
3. The speed limit is the reason for the increase of travel time in the steep track sections.

The adverse effect of the braking force on the superstructure of the railway is increasing by increasing the slope. It is necessary for the railway superstructure to be with more reliability construction in these sections.

6. Literature


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